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COOPERATIVE DEDICATED VESSEL RESEARCH PROGRAM

Research Related to the Tuna-Porpoise Problem:
Summary of Research Results from the
Second Cruise of the Dedicated Vessel
17 April to 5 June 1978

by

James M. Coe, National Marine Fisheries Service
Jacqueline G. Jennings, National Marine Fisheries Service
Charles B. Peters, Living Marine Resources, Inc.
John DeBeer, Program Manager

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NOAA, National Marine Fisheries Service
SWFC Honolulu Laboratory F/SWC2
2570 Dole Street
Honolulu, HI 96822-2396

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ABSTRACT

The tuna industry and the Federal Government sponsored the tuna seiner M/V Queen Mary during 1978 as a research platform for studies related to the tuna/porpoise problem. Between April 17 and June 5, 1978, the Queen Mary carried the Porpoise School Impoundment System (PSIS) to the eastern tropical Pacific to determine its efficacy and to develop procedures for examining whole schools of porpoise. The PSIS, designed by the National Marine Fisheries Service, consists of a system of interconnected nets, aluminum cages, and chutes. The system is attached to the purse seine corkline at the porpoise release area during backdown to allow transfer of the animals from the seine into the apparatus.

During the cruise, 22 sets were made on porpoise; of these, four were PSIS sets, four were aborted PSIS sets, and 14 were sets to allow research on rescue technology and behavioral observations. Use of the PSIS was found to be limited by weather (Beaufort 3-4 or less), evasive behavior of the porpoise school before the set, the total number of porpoise captured (maximum feasible number estimated at 500), remaining daylight hours (≥ 6 hours required) and the number of eastern spinners captured (feasible maximum of about 50). The PSIS mission was aborted in mid-set four times because of a large number of spinner porpoise, imminent net collapse or multiple speedboat breakdowns. In the four successful PSIS sets, evasive behavior of the target porpoise schools resulted in the examination of only partial schools in three cases. A total of 398 offshore spotted porpoise, Stenella attenuata, and 43 eastern spinner porpoise, Stenella longirostris, were aged, sexed, measured and released alive. In the fourth PSIS set, 53 offshore spotted porpoise were confined in a free-floating holding pen for seven hours, with no mortality and no marked behavioral changes. Seventeen porpoise died during the PSIS operations.

The successful development of the PSIS for handling and releasing large numbers of oceanic porpoise provides future researchers with a means to carry out studies of school structure, population density and migration, and physiological parameters.

Neither porpoise nor tuna behavior was influenced by magnesium flares suspended in the net. Underwater observations gave some insight into the causes of a net folding problem during backdown termed "stern sway" but did not produce any immediate solutions. Tissue samples for histopathological examination, aging studies, and porpoise and tuna diet studies were collected.

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PREFACE

Thousands of oceanic porpoise are incidentally killed or seriously injured each year during the course of purse seining for yellowfin tuna in the Eastern Tropical Pacific (ETP). A goal of the Marine Mammal Protection Act of 1972 is to reduce the incidental kill and the serious injury rate to insignificant levels approaching zero. Numerous fishing trips and research cruises since 1972 have contributed to the development of methods for reducing this incidental mortality by a significant amount; however, no single vessel has been designated to study and research this problem exclusively.

During all previous research cruises aboard tuna purse seiners the research was secondary to the capture of tuna, because the incentive to allow the researchers to work aboard tuna seiners was the opportunity to capture a special allocation of tuna within a closed area.

For a number of years, it has been recognized that a vessel should be dedicated for tuna/porpoise research free of pressures induced by fishing that impede research. In 1977 the United States Tuna Foundation agreed to charter a tuna purse seiner for exclusive tuna/porpoise investigation in 1978.

The Dedicated Vessel Program is a cooperative tuna/porpoise research program under the joint direction of the Marine Mammal Commission (MMC), the National Marine Fisheries Service (NMFS), and the United States Tuna Foundation (USTF). The USTF chartered the commercial tuna seiner, M/V Queen Mary, to be used as a platform for that research. NMFS, USTF, the National Science Foundation (NSF), and the MMC provided research funds and/or support. Proposals for relevant research were accepted from all interested persons and organizations.

The overall research plan provided for five cruises of 50 days each. The goals were to: 1) refine and develop fishing gear and/or practices to further reduce the incidental mortality rate; and 2) provide demographic and biological data needed to better assess the impacted porpoise stocks.

This report summarizes the research activities carried out during the second cruise of the Dedicated Vessel. Mr. James M. Coe, NMFS, plans to write a detailed operations manual on the use of the Porpoise School Impoundment System (PSIS) and Ms. Jacqueline G. Jennings, NMFS, plans to write a detailed report for publication describing the development of the PSIS. Mr. William Walker, a NMFS contractor, and Dr. C. Cowan, University of Texas Medical School, will submit a contract report on porpoise pathology to NMFS in April, 1979.

I. INTRODUCTION

The National Marine Fisheries Service (NMFS) and the United States Tuna Foundation (USTF) provided research funds for Cruise II of the Dedicated Vessel. Scientific personnel came from NMFS and Living Marine Resources, Inc. (LMR). They were James M. Coe, Jacqueline G. Jennings, Dr. Warren Stuntz, James Lambert, all from NMFS; William Walker, an NMFS contractor; and Charles B. Peters, LMR.

The cruise departed from San Diego on 17 April and returned to San Diego on 5 June 1978, a 50-day trip.

The area of research operations was the yellowfin tuna fishing grounds off Mexico and Central America, both inside and outside the Inter-American Tropical Tuna Commission Regulatory Area (CYRA). The general cruise track is shown in Figure 1.

II. VESSEL AND EQUIPMENT

The M/V Queen Mary, built in 1969, is 151 feet long, has a 34-foot beam and a 17-foot draft. She is propelled by twin Caterpillar diesel engines, 1125 hp each, and has a maximum speed of 12.5 knots. She is equipped with a Caterpillar 333 bowthruster, a Marco #W1062 main winch, and a 42-inch power block. The vessel can carry, depending on fish size, from 520 to 550 tons of tuna in seven pairs of brine wells and one pair of stern boxes. The net is 560 fathoms long, 11 strips* deep, with 190 fathoms of double-depth safety panel (1 1/4-inch mesh) and a super apron.

The principal research equipment used on Cruise II was a Porpoise School Impoundment System (PSIS) designed and constructed by NOAA's National Fisheries Engineering Laboratory (NFEL), Bay St. Louis, Mississippi, and Southwest Fisheries Center (SWFC), La Jolla, California. The PSIS was developed so that individual porpoise can be handled and examined safely. It is a system of interconnecting nets and aluminum cages, consisting of a corral and waiting pen, two work areas, and a holding pen, that can be attached if needed. A diagrammatic overhead view of the corral, waiting pen, and work areas is presented in Figure 2. The relationships of the PSIS, the backdown channel, and the vessel during use are shown in Figure 3.

The PSIS was carried on the bow of the Queen Mary; a 3-ton capacity crane was installed on the bow to launch and retrieve it. To accommodate

*A standard strip of webbing is one hundred 4 1/4-inch meshes deep.

OBSERVER	NO. OF SETS	22
1	1	1
2	1	1
3	1	1
4	1	1
5	1	1
6	1	1
7	1	1
8	1	1
9	1	1
10	1	1
11	1	1
12	1	1
13	1	1
14	1	1
15	1	1
16	1	1
17	1	1
18	1	1
19	1	1
20	1	1
21	1	1
22	1	1
23	1	1
24	1	1
25	1	1
26	1	1
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90	1	1
91	1	1
92	1	1
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96	1	1
97	1	1
98	1	1
99	1	1
100	1	1

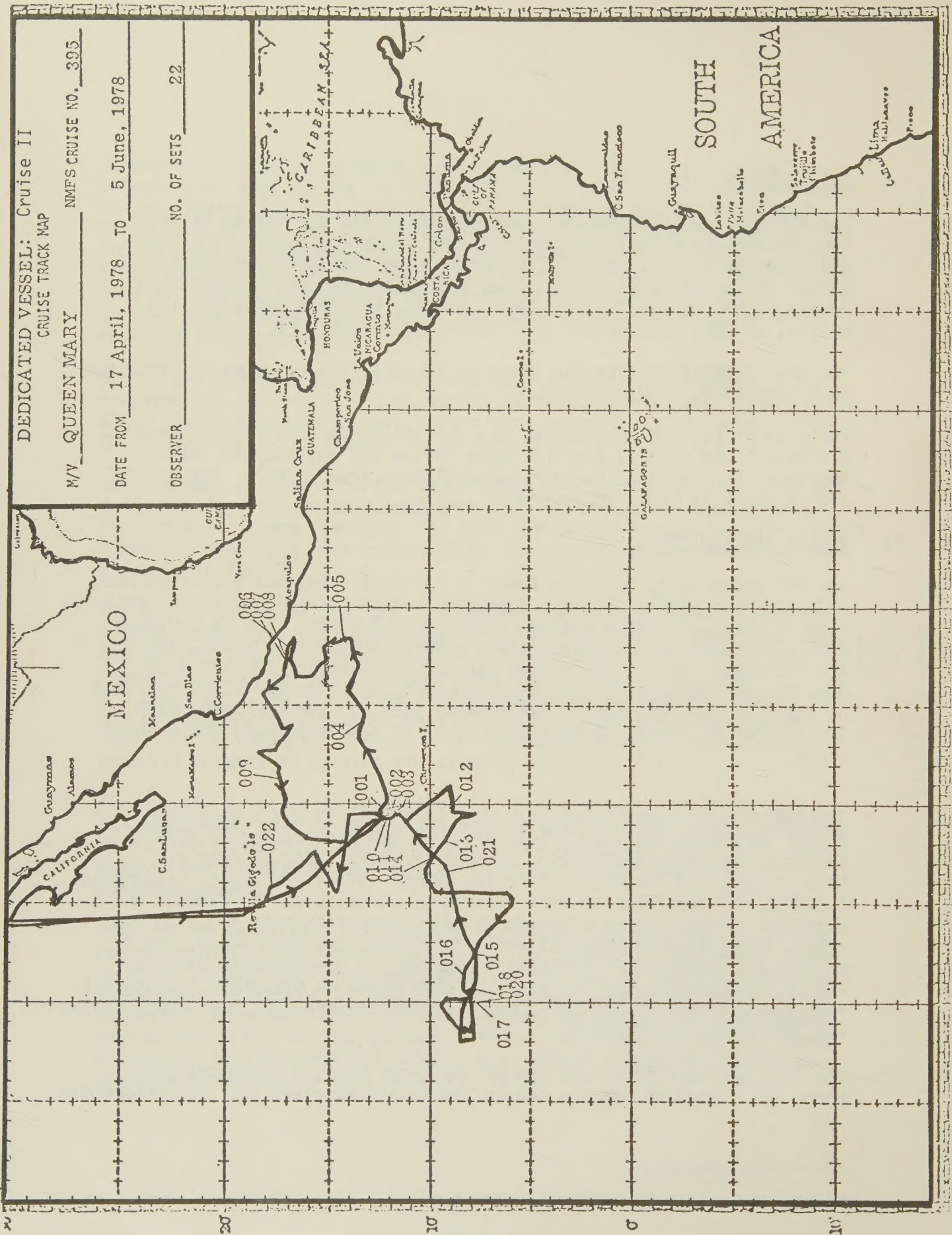


Figure 1

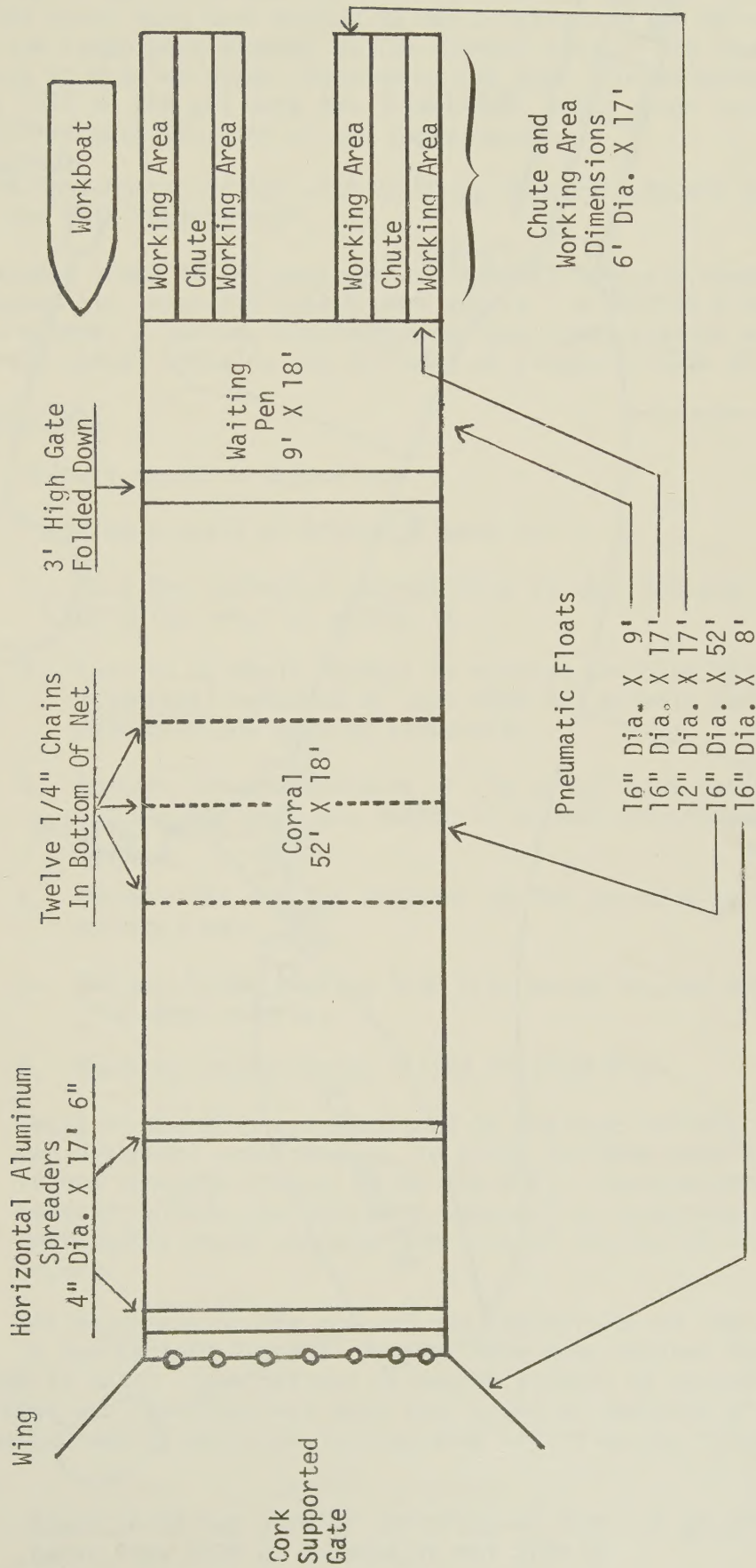


Figure 2. Schematic of the Porpoise School Impoundment System (PSIS)

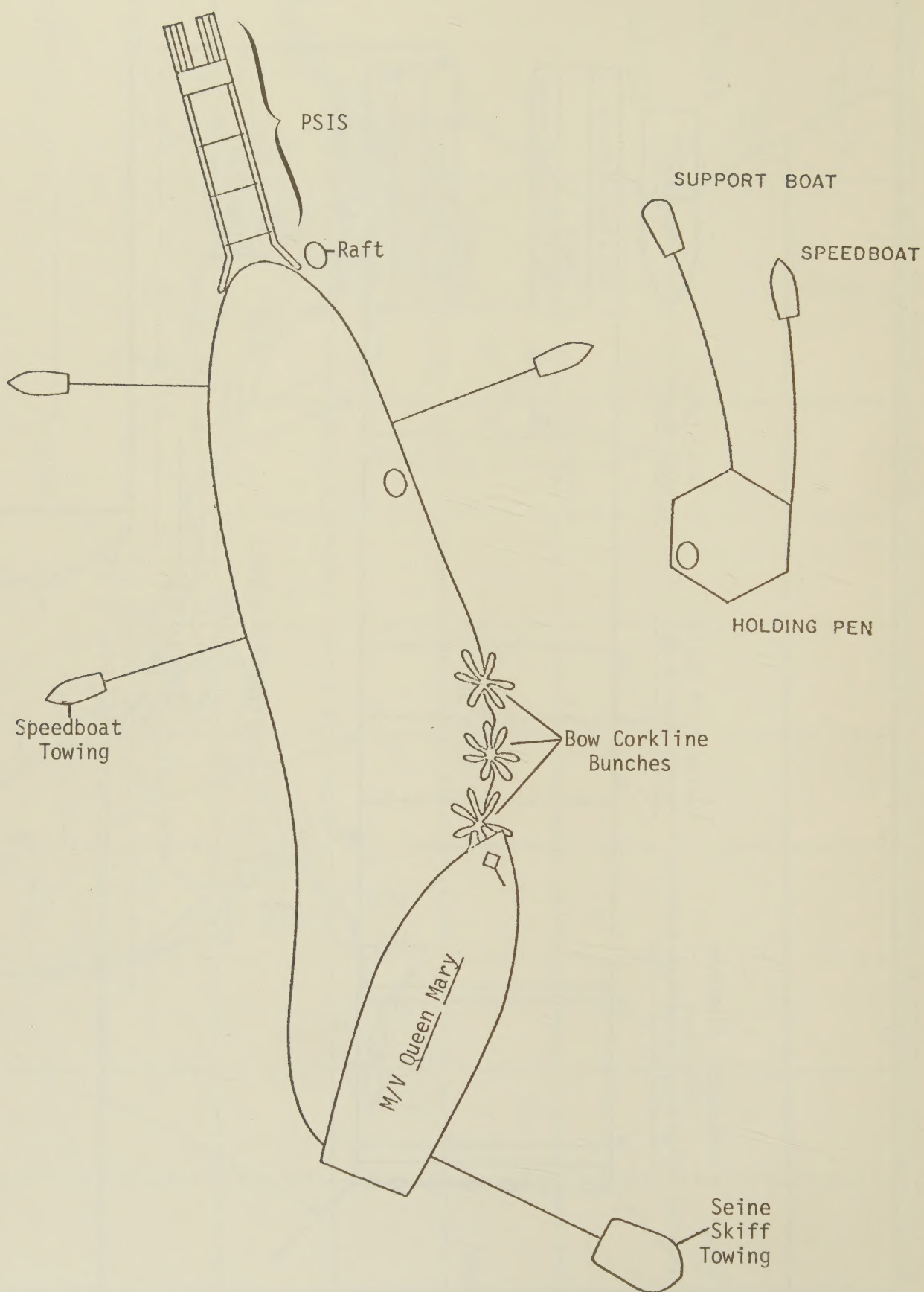


Figure 3. PSIS in position, holding pen being towed to PSIS for attachment to PSIS work areas.

the PSIS, the large mooring bitt was removed and two steel cleats and eight steel eyes were welded to the bulkheads. Two 500-watt Quartzite marine lamps were mounted on the forward edge of the roof of the pilot house to provide night lighting on the bow. The attachment points for the PSIS on the net were two 3-inch I.D. steel rings installed on the corkline near the apex of the super apron.

A 16-foot Boston whaler with an 85-hp Mercury outboard engine served as the PSIS support boat.

Standard SCUBA diving gear and an Ingersoll-Rand air compressor with a cascade air reservoir system were aboard. A YAK-YAK transducer/hydrophone, a two-way underwater/surface communication system required by the vessel Captain, was included as standard SCUBA diving gear.

III. OBJECTIVES

A. Primary Research Objectives

The primary goals of Cruise II were to:

1. Test the mechanical workability of the PSIS and observe porpoise behavior within it.
2. Examine 22 whole schools of spotted porpoise (Stenella attenuata) composed of less than 500 animals each, to determine age and sex structure.
3. Compare visual estimates of the school size during the chase and capture with the number of animals processed through the PSIS.
4. Observe the evasive behavior of the porpoise before and during a set.
5. Collect blood samples from live porpoise, and adrenal glands from dead animals.
6. Necropsy any porpoise killed incidentally.

Tests of the PSIS were designed to evaluate mechanical performance and personnel requirements, to allow for more precise planning of future research cruises using the PSIS. Observations of porpoise behavior within the PSIS were intended to determine whether close confinement would increase the risk of incidental mortality or injury.

All estimates of the age and sex composition of the porpoise stocks in the Eastern Tropical Pacific have been derived from incidental kill data. Examinations of entire schools of porpoise would yield age and sex structure data that could be compared with the age and sex data of porpoise incidentally killed by the purse seine fleet

in a similar time and area strata. These examinations would help validate whether or not the assumption that the incidental kill is random and, thus, a true indicator of the life history parameters of the stock.

Several types of sets were planned to define the workability of the PSIS and to examine whole schools of porpoise. The initial testing of the PSIS was to occur in the waters off San Diego and, if the PSIS could be launched, assembled and retrieved safely, further testing was to occur on the tropical fishing grounds. If the PSIS proved to be mechanically workable, it would then be used to examine a small school of porpoise (≤ 50 animals) to observe the reaction of the porpoise to confinement and examination. The PSIS could then be used to examine larger whole schools of porpoise. The numerical goal for whole schools of porpoise to be examined on Cruise II was 22.*

The objective of examining only whole schools of porpoise was modified in mid-trip because few whole schools were encountered that were small enough to be examined and because, although some schools were small enough initially, some animals escaped during the chase so that the entire school was not captured.

Because an actual census of a porpoise school could be obtained with the PSIS, another objective was to compare the visual estimates of the school size before and during the set with the number of animals known to have been processed through the PSIS. A comparison of this type may establish the reliability of visual estimates of porpoise school size.

Observing and quantifying the evasive behavior of porpoise schools was important to allow planners of future cruises using the PSIS to more closely predict the number of porpoise that could be captured or that may escape.

Blood samples were to be collected during PSIS sets to ascertain physiological responses to chase and capture, especially capture myopathy, which may lead to estimates of unobserved fishing-related mortality. Up to 100 blood samples were to be taken from the fluke veins of spotted porpoise as they passed through the PSIS chutes. Adrenal glands were to be collected and frozen from all dead porpoise for the same research.

All porpoise killed were to be necropsied to survey disease processes and parasites to refine estimates of the natural and fishery-induced mortality rates.

*Based on variance of structure ratios in large, single school samples from the NMFS observer program, an analysis of the number of schools that needed to be examined for the school-structure was done by Dr. Nancy Lo, NMFS. She estimated that at least 22 schools should be examined to obtain a confidence interval of 95% probability.

B. Secondary Research Objectives (Gear/Behavior)

Sets not involving the PSIS were designated as "gear sets," and one or more of the following objectives were to be pursued:

1. Study and observe the backdown channel to maximize its efficiency by:
 - a. Measuring the surface dimensions of the backdown channel.
 - b. Having divers with SCUBA gear examine the stern wall of the net while the net was being rolled aboard and examine the net through backdown, to determine the effects of prebackdown net shape on the amount and existence of stern sway.*
 - c. Measuring the depth of the floor of the backdown channel as backdown progressed and determining the relationship between the floor rise and the occurrence and severity of stern sway.
 - d. Adjusting the net hang-in on the bow and stern sides of the backdown channel, to determine if changes in hang-in rate could alleviate backdown canopy formation.
 - e. Documentating completely all vessel-control aspects of backing down to study the causes of backdown canopy formation.
2. Study the operational aspects of purse-seine fishing that cause delays and contribute to porpoise mortality, such as rollups, net caught on the stern, or bunchline fouling by:
 - a. Recording the operational aspects of sets with rollups, such as 1) winch use, 2) rudder use during setting, 3) position of rollup on the purse cable and net, and 4) the anatomy of the rollup as it is unrolled.
 - b. Photographing the contact of the net with the vessel's stern during pursing to identify the causes of the net entanglement on the propeller and rudder.
 - c. Observing and recording the causes of bunchline fouling, to develop ideas to eliminate this problem.
3. Remove some of the corks at the backdown apex and maneuver the vessel just prior to backdown, to continue testing pre-backdown release.

*Stern sway is the term applied to the in-folding of the stern wall of webbing of the backdown channel that contributes to porpoise mortality by occasionally blocking their direct passage to the surface.

4. Test various stimuli before and during backdown to identify any that could be used to enhance porpoise release efforts. The stimuli to be tested were:
 - a. Bubble-screen devices for holding or herding porpoise in the backdown channel.
 - b. Underwater strobe lights.
 - c. Underwater magnesium flares.
5. Make surface and underwater observations of porpoise behavior in the seine and quantify the following items:
 - a. The age structure of rafting animals.
 - b. The proportion of rafting porpoise in the school.
 - c. The age structure and number of animals that are "passive" during backdown.

C. Ancillary Research Objectives

Other, lower-priority research objectives were to:

1. Collect all porpoise stomachs from each set on Delphinus delphis in which five or more porpoise are killed and flag at least 40 yellowfin tuna from any such set, so the stomachs could be recovered later for comparisons of porpoise and tuna diets. Similar collections were to be made for sets on Stenella spp. that occurred prior to 0900 and after 1500.
2. Collect the standard NMFS life history data from each dead porpoise plus the following biological samples:
 - a. A single eye. The eye lens protein will be used for biochemical age estimation which will be compared to the age determined by examination of the teeth.
 - b. Tissue samples from at least three spotted porpoise (a calf, <120 cm; a juvenile, 120-160 cm; and an adult, >160 cm), for a study of the relationships between various structural lipids and lipids in the diet. The tissues were: skeletal muscle, liver, heart, and aorta. They were to be at least 100 grams each and quick frozen in the liquid nitrogen.
3. Maintain a marine mammal watch during daylight hours. Sighted marine mammals were to be photographed if possible. The NMFS research set log was to be completed for each set and the Fishing Mode Record was to be kept.

4. Launch an XBT probe each day at noon and one during each set. The XBT data along with the weather data were to be radioed to WWD daily.

IV. METHODS AND RESULTS

An estimated* 14,700 porpoise were pursued and 5,850 were captured, with 159 tons of yellowfin tuna in 22 porpoise sets. The PSIS was used in four sets. There were 14 gear sets and four aborted PSIS sets.** Summaries by set type are presented in Table 1, and data for each individual set is presented in Table 2. A narrative summary for each successful and aborted PSIS set is presented in Appendix A.

Table 1. Summary by Set Type

Type	# Sets	Porpoise Chased	Porpoise Captured	Porpoise Killed	Porpoise Examined	Tons Tuna	Kill Set	Kill Ton
PSIS	4	1615	611	17	447	7	4.25	2.43
Aborted PSIS	4	3077	1052	9	-	41	2.25	0.22
Gear	14	9978	4188	26	-	111	1.86	0.23
Total	22	14700	5851	52	447	159		

A. Results of Primary Studies

1. Testing PSIS

a. Mechanical Workability

The PSIS underwent four days of sea trials off San Diego. During that time, the scientists and ship's crew learned to launch and retrieve the PSIS. The system proved to be seaworthy, although minor rigging and procedural changes were required as the testing progressed.

The general procedure for using the PSIS was to launch the corral and waiting pens over the starboard bow shortly before the net was pursued. Launch completion and assembly occurred on the starboard side of the vessel simultaneously with the net being rolled aboard. The assembled PSIS was

*All estimates of porpoise school size are crew estimates, unless otherwise stated.

**These sets were made with the intent to use the PSIS. However, prevailing circumstances dictated that it not be used because of a high potential for injury to personnel or porpoise mortality.

TABLE 2. Summary of Set Log Data

Set no.	Date	Latitude	Longitude	Time set	Avg. crew est. of school		* Ton start YF	Time start 30	# of BD's	# Rescued during BD	# Rescued after BD	Total elapsed time (hrs.)	HALF delay (min.)	# spot. killed	#E. spin. killed	#K3 spin. killed	Fun-known spp. killed	Total killed	
					Spot.	Spin.													
001	4/22	12°14'N	110°13'W	1237	483	92	18	14	1333	1	0	2.4	0	0	0	0	0	0	Gear/scuba
002	4/23	11°56'N	110°20'W	1642	950	60	0	8	1753	1	3	2.6	10	0	0	0	0	0	Gear/flare
003	4/24	11°17'N	110°05'W	1127	575	0	0	1	1341	2	16	4.6	0	1	0	0	0	1	PSIS/partial school
004	4/27	13°18'N	105°50'W	0850	681	36	0	4	1031	2	0	4.9	0	8	0	0	0	8	PSIS/partial school
005	4/29	14°28'N	101°54'W	1615	80	0	0	0	1709	1	0	1.6	0	0	0	0	0	0	Gear/scuba
006	5/4	16°45'N	102°06'W	0839	355	712	10	2	0943	1	3	2.0	0	0	0	0	0	0	Gear/flare
007	5/4	17°06'N	102°29'W	1326	562	183	0	0	-	0	-	1.4	0	0	0	0	0	0	Gear/measure
008	5/4	17°05'N	102°27'W	1336	788	262	0	0	-	0	-	1.7	0	0	0	0	0	0	Gear/measure
009	5/8	17°23'N	103°41'W	1506	93	0	13	0	1500	1	0	1.6	0	0	0	0	0	0	Gear/measure
010	5/12	11°57'N	110°30'W	0744	200	300	111	206	15834	1	0	1.7	0	0	0	0	0	0	PSIS/aborted
011	5/12	11°25'N	110°06'W	1259	165	85	165	85	1500	3	0	5.0	0	3	3	0	2	8	PSIS/whole school
012	5/13	8°53'N	110°04'W	0812	470	288	274	168	15916	1	0	1.9	0	0	0	0	0	0	Gear/measure
013	5/14	9°12'N	111°55'W	1720	397	70	322	78	1812	1	4	2.0	0	0	0	0	0	0	Gear/flare
014	5/15	9°41'N	112°33'W	1143	1113	1028	12	295	1247	1	4	1.9	0	0	0	0	0	0	PSIS/aborted
015	5/16	7°47'N	117°36'W	1436	1201	924	380	570	1535	1	0	2.3	0	0	0	0	0	0	Gear/measure
016	5/19	8°14'N	118°32'W	1018	197	6	163	5	1118	1	5	2.4	5	3	0	0	0	3	PSIS/scored
017	5/20	8°09'N	119°31'W	0915	233	0	233	0	0930	1	25	4.0	0	5	0	0	0	6	PSIS/aborted
018	5/20	7°50'N	119°09'W	1844	225	0	150	0	1943	1	4	2.8	0	0	0	0	0	0	Gear/flare
019	5/20	8°03'N	121°32'W	0711	1156	61	1103	53	0810	1	87	4.2	0	24	0	2	0	26	Gear/measure
020	5/24	7°50'N	120°00'W	1640	7	164	7	164	1731	1	0	1.9	0	0	0	0	0	0	Gear/measure
021	5/25	9°15'N	113°19'W	0931	67	36	41	1	1205	1	0	10.6	0	0	0	0	0	0	PSIS/holding pen
022	5/1	17°36'N	114°27'W	1419	450	0	450	0	1515	1	2	2.4	0	0	0	0	0	0	Gear/measure
Total: all sets					9498	4252	4120	1660	159	155	1	3.2	15	45	0	2	2	52	
					950 no comp.														

*Tonnages are estimates made at the time of loading.

moored next to the seiner until the crew was ready to backdown. Before backdown, it was towed into position and the corral was attached to the apron at the apex of the backdown channel (Figure 3). The launch and retrieval sequence in relation to the timing of a set is presented in Table 3.

After the PSIS was attached to the net, the seiner was backed down, the corks at the apex of the backdown channel sank and the porpoise spilled into the corral. Ideally, every porpoise captured in the seine would have been examined through the PSIS and released alive and unharmed. However, this did not happen; some porpoise always escaped over the sides of the backdown channel during backdown. The absolute number of porpoise that were to be backed into the corral in each backdown could not be accurately gauged, because during backdown the porpoise did not enter singly but entered in fairly large groups. If there were too many porpoise in the corral after backdown ceased, rescuers released the excess animals over the corral gate back into the seine, until a manageable number remained, and the actual processing could begin.

Multiple backdowns were required on two of the four PSIS sets, because there were too many porpoise to process in a single backdown. After the first backdown stopped, speedboats made fast to the corkline and held the backdown channel open, while the animals in the corral were processed. After the corral was cleared of animals, the speedboats were untied and backdown was repeated.

During processing, tenders brought individual porpoise to the waiting pen and guided them into the chutes of the working areas. Scientists standing in the work areas examined each porpoise, noting its species, color pattern, length and sex and then released it, either back into the ocean or into a holding pen.

b. Porpoise Behavior within the PSIS

An important part of testing the PSIS was to note the porpoise behavior within it. Quantifying this behavior was not possible, because all the researchers were either rescuing entangled porpoise, guiding porpoise into the chute, or examining the porpoise; however, general porpoise behavior was noted. During backdown, some animals always tried to re-enter the seine over the interface of the corral gate and corkline. During the four PSIS sets, 91 porpoise escaped over the corkline of the seine and never entered the corral.

TABLE 3. TIMING OF EVENTS; PSIS SETS

Set School no. sighted	Launch boats go	Net let of PSIS launched	First piece of PSIS launched	Rings up	Net tied down for backdown	Release PSIS	PSIS attached to seine	Launch holding pen	Holding pen attached	1st BD (# porp.) into PSIS	2nd BD (# porp.) into PSIS	3rd BD (# porp.) into PSIS	PSIS detached	Process last porpoise aboard	Seine skiff aboard	Retrieval of PSIS begins	PSIS aboard	H.P. aboard	Total Time Req.
003 1017	1111	1127	1140	1200	1225	1234	1335	--	--	1341 (~90)	1355 * (0)	--	1352	1423	1435	1500	1600	--	5 Hrs 43 Min
004 0800	0831	0850	0910	0920	0946	0950	1019	--	--	1028 (127)	1123 (67)	--	1155	1147	1254	1300	1345	--	5 Hrs 43 Min
011 1210	1252	1259	1328	--	1355	~1420	~1455	--	--	1500 (62)	1527 (48)	? (14)	--	--	1710	1720	1810	--	6 Hrs
021 0850	0915	0931	~1000	1005	1028	~1030	~1055	~1110	~1200	1205 (53)	--	--	1236	1236	~1320	1330	1410	2005	5 Hrs 20 Min**

*PSIS was detached from the seine, and the animals remaining in the seine were released via a normal backdown.

**Does not include monitoring the animals in the holding pen.

-Corral and Waiting Pen

Spotted porpoise remained calm within the corral, even when they came in contact with the webbing. They rafted very tightly and, as a group, avoided contact with the corral walls, although this was not always possible because of the swells and their own movement. They continuously moved away from the aluminum waiting pen toward the crowder net.

Individuals rammed the walls and the bottom of the corral with their snouts; consequently some were snagged by their teeth. They were generally unable to free themselves, and the tenders had continuous physical contact with the spotted porpoise, which showed little avoidance of this contact.

"Passive" porpoise behavior was observed within the corral occasionally. The animals rested on the bottom of the corral (individually or in groups) for up to two minutes (rough estimate) then surfaced for air.

Eastern spinners required twice the time and effort of an equivalent number of spotted porpoise to process. They continuously got entangled in the corral webbing, requiring extensive and immediate attention from the tenders. Snagged eastern spinners struggled much more than spotted porpoise; a single vigorous animal often required several men to pacify and untangle it.

-Work Area and Chute

Most spotted porpoise were reasonably docile and could be caught and delivered to the work areas with little difficulty. In the chute, many of the spotters and eastern spinners arched dorsally or laterally, making them difficult to measure. A few attempted to swim in the chute but usually settled down in a few seconds.

-Holding Pen

Spotted porpoise were the only porpoise held in a holding pen. After processing, 53 spotters were released directly into a holding pen where they were held for 7 1/2 hours before being released.

Although the first three or four porpoise to enter the holding pen appeared disoriented and bumped into the webbing a few times before they began to raft and mill about in the center, no rescue was required. Animals subsequently entering the pen joined the oriented group and avoided contact with the walls of the pen. Even when the pen was severely folded by the wind and swell at one point, the porpoise remained calm. They were easily herded and pushed out of danger

by swimmers. The few passive animals on the bottom of the holding pen, while it was collapsed, merely rose to the surface when air was required. No passive behavior was noted when the holding pen was open and stable.

-Release

When released from the chute, spotted and eastern spinner porpoise traveled up to an estimated 100 yards prior to surfacing. Animals of both species appeared to be disoriented upon surfacing, traveling in various directions before they chose a steady path. Their jumps were shorter and running speed slower than has been observed upon release from a seine. Some juvenile spotters returned to the PSIS area and became entangled in the webbing on the outside of the corral.

2. Porpoise School Structure

There were 447 porpoise examined in the four PSIS sets. Nearly an entire school of 81 spotters and 43 spinners was examined on one set, and 323 spotters were examined during three other sets. The composition of porpoise examined is summarized in Table 4.

Table 4. Summary of Age and Sex Data of Porpoise Examined through the PSIS

Offshore Spotted porpoise			Eastern Spinner porpoise	
Age	Male	Female	Male	Female
Neonate	1	6	Unable to Ascertain Age	
Two-tone	22	28		
Speckled	15	32		
Mottled	17	15		
Adult	99	169		
Total	154	250	31	12
	38%	62%	72%	28%

The school composition data collected from each PSIS set are summarized in Table 5. The data collected from offshore spotted

TABLE 5. SUMMARY DATA FOR PORPOISE EXAMINED IN PSTS SETS INCLUDES ALL ANIMALS WHETHER RELEASED ALIVE OR KILLED

Set no.	Offshore Spotted Dolphins										Eastern Spinner Dolphins		Offshore Spotted Dolphins	
	Males					Females					Total examined Males	Total examined Females	Total examined Males	Total examined Females
	Neonate	Two-tone	Speckled	Mottled	Adult	Neonate	Two-tone	Speckled	Mottled	Adult				
A. PARTIAL SCHOOLS														
003 *	0	2 172	1 165	4 189	21 198	0	1 160	3 172	3 183	31 188	--	--	28 (42%)	38 (58%)
004 *	0	13 (2 dead) 148	11 168	7 174	49 202	2 105	15 (1 dead) 143	22 166	4 181	81 (2 dead) 188	--	--	80 (39%) (2 dead)	124 (61%) (3 dead)
021 *	0	3 128	0	1 184	11 200	0	5 127	1 168	2 173	30 188	--	--	15 (28%)	38 (72%)
TOTALS *	0	18 147	12 168	12 180	81 201	2 105	21 140	26 167	9 180	142 188	0	0	123 (38%)	200 (62%)
B. WHOLE SCHOOLS														
011 *	1 100	4 121	3 156	5 175	18 196	4 (1 dead) 95	7 (1 dead) 129	6 (1 dead) 163	6 172	27 183	31 (72%)	12 (28%)	31 (38%)	50 (62%) (3 dead)

*Average length (cm)

porpoise are summarized by sex and color pattern (age). The average length of the porpoise displaying each color pattern and the sex ratio of the stock are also included. Part A of Table 5 summarizes the data from the partial schools examined, and Part B summarizes the data from the whole school in which nearly-all the animals were examined.

3. School Size Estimates Compared to Actual Counts

Estimates of the school size before the set and of the school size captured were made by the captain, navigator, a crew member, and members of the scientific party with purse seining experience. The combined estimates of porpoise captures as well as the best count are presented in Table 6.

Table 6. Estimates and Actual Counts of Porpoise School Size Captured in the PSIS Sets

Set #	Species Composition	Average Est. of Porpoise Captured	Range of Estimates	Best Count of Porpoise Captured	% Difference
3	Spotters	98	80 150	138	-29
4	Spotters	256	200 350	268	-4
11	Spot/Spinners	261*	200 275	136	+91
21	Spotters	43	35 55	56	-23

An analysis of the data reveals that on one set the average estimate of animals captured was within 5 percent of the true count, and on two sets the average estimate was within 30 percent of the actual count. On those three sets the estimates were lower than the actual count, and the schools captured contained only spotters. On the one set that spinners were captured, the estimated number of porpoise captured was almost twice as high as the actual count. A detailed summary of the estimated school size before capture, the school size captured and the best count of porpoise captured is presented in Table 7.

The employment of the PSIS occupied the full attention of the crew and scientific party. The individuals making the school size estimates mentally recorded their estimates until after

*The entire school was captured, but seven porpoise escaped during the three backdowns.

TABLE 7. DISPOSITION OF CAPTURED PORPOISE IN PSIS SETS

Set #	Avg. crew est. of school size (N)	Avg. sci. party est. of school size (N)	Avg. crew est. of porpoise captured (N)	Avg. sci. estimate of porpoise captured (N)	Count or est. of # escaped/released			Killed in seine	Killed in corral	Killed in H.P.*	Killed outside seine, corral or H.P.	Total porpoise processed alive	Best count of porpoise captured
					1st BD Esc./Rel.	2nd BD Esc./Rel.	3rd BD Esc./Rel.						
003	575.00 (2) 100% spot	356.25 (4) 100% spot	106.67 (3) 100% spot	83.75 (2) 100% spotters	20/16	0/35	---	0	0	---	1 (shark)	66	138
004	611.66 (3) 5% East. spinners	500.00 (2) 100% spot	212.50 (3) 100% spot	300.00 (3) 100% spot	41/0	20/0	---	5	3	---	0	199	263
011	250.00 (3) 34% East. spinners	268.75 (4) 30% East. spinners	250.00 (3) 34% East. spinners	268.75 (4) 30% East. spinners	3/0	3/0	1/0	2	1	---	5 (two after processing)	123	136 35% E. spinners
021	103.33 (3) 34% East. spinners	128.33 (3) 17% East. spinners	42.50 (2) 25% East. spinners	42.50 (3) 100% spot	3/0	---	---	0	0	0	0	53	56

*Holding pen

the set was completed. This created a potential for biasing of capture estimates that could not be avoided. All of the estimators were asked not to adjust their estimates, regardless of how inaccurate they may have been.

4. Evasive Techniques

a. Evasive Behavior during a Chase and Set

Six of the 22 porpoise sets were made on pure schools of spotted porpoise, and mixed schools of spotters and spinners constituted the remaining 16 (Table 2). On only 30 percent of the sets (six) were all of the porpoise thought to be present at the beginning of the chase captured. Some fraction of the school avoided capture on the remaining 16, including two sets in which no porpoise were captured.

The average size estimates of the schools chased ranged from 80 to 2140 porpoise and averaged 668 porpoise per school. The average size estimates of the schools captured ranged from 0 to 1167 porpoise, and there was an average of 265 animals captured per set. Thus, an estimated 40 percent of the animals chased were captured.

On 18 chases that resulted in sets, the porpoise started running from the seiner and speedboats, at an estimated three miles distance. However, the speedboats would quickly overtake the porpoise and attempt to herd them in a counter-clockwise circle. On five of these sets, the porpoise remained inside the circle inscribed by the wake of the purse seiner. On the remaining 13 chases, the porpoise did not respond, and some escaped encirclement by a) diving and surfacing outside the speedboats circle, b) crossing the bow of the encircling vessel after the skiff was released, and c) diving under the seine at the halfnet mark or on the bow side after the seine had encircled them. These escape maneuvers were carried out en masse or by subgroups of 10 to 100 animals. The subgroups appeared to consist of single-species aggregations.

If the porpoise school did not run from the approaching vessel at an estimated three miles (Sets 5, 7, 8, 20), it would begin to run slowly when the vessel was about 100 yards distant. The entire school was captured on one of these four sets (Set 20). Animals escaped on the other three sets either during encirclement with the seine or after encirclement and prior to "rings up." On two

occasions, all the animals encircled escaped and on the other, an estimated 70 of the 90 animals encircled escaped. They jumped, flipped and surfed in the bow and stern wakes of the vessel during the chase and encirclement. Prior to release of the skiff, they would occasionally pass through the stern wake of the vessel, which usually stops schools. They tried to exit in front of the skiff during encirclement. After encirclement, they escaped by diving under the towline and any point along the seine.

b. Evasive Behavior during Aborted Chases

An aborted chase is one in which the speedboats are launched and pursue a school but are picked up without setting the net. There were 14 such chases on this cruise. Five were aborted because of school size, sea state or species composition of the school. Nine chases were aborted because the porpoise evaded the speedboats by spreading out or were lost in a rain squall (Table 8).

Prior to the chase, a school may be scattered over an area of one or two square miles, or it may spread out over this large area during the chase. When it appeared that a school could not be sufficiently bunched up so a significant number of porpoise would be encircled, the chase was stopped. This occurred six times. On three occasions, there were rain squalls nearby and the porpoise were lost when they ran into them.

5. Blood Samples and Adrenal Glands

No blood samples or adrenal glands were collected.

6. Necropsies

Thirty-two porpoise were necropsied from all sets (29 *S. attenuata* and three *S. longirostris*). Detailed accounts of all visible lesions in the major organ systems were recorded, and tissue samples from all organ systems were preserved for later histopathological laboratory examination.

B. Results of Secondary Research (Gear/Behavior)

During the 14 non-PSIS sets and one of the aborted PSIS sets (Set 16), mortality-reduction research was conducted. The scope of this research was limited, because the primary objectives of the cruise required use of the PSIS. Use of the PSIS was restricted to fair weather and the early portion of the day (<1400). Thus, the gear sets were generally made late in the day and in fairly rough weather.

1. Observations of the Backdown Channel

The backdown channel was very well-formed, except for a slight stern sway that is discussed below. It had a bowl-shaped, gradually sloping apex, and there were no canopies.

Table 8. Estimated Number of Porpoise by Species Contained in Schools that were Chased but Not Set Upon.

Date	Spotted	Eastern Spinner	White Belly Spinner	Streaker	Total	Beaufort Weather	Comment
4/23	420	180	0	0	600	3	Not pure spotted school
4/26	100	990	0	0	1,090	3	Not pure spotted school
5/8	50	0	0	0	50	5	Evaded
5/13	2,700	0	300	0	3,000	5	Evaded
5/13	2,700	0	300	0	3,000	5	Rain squall
5/14	0	0	0	500	500	2	Not pure spotted school
5/15	1,600	0	400	0	2,000	1	Evaded
5/23	150	0	0	0	150	6	Evaded
5/23	400	0	400	0	800	6	Rain squall
5/24	12	0	0	0	12	3	Small school
5/26	625	0	1,875	0	2,500	4	Evaded
5/26	200	0	200	0	400	4	Rain squall
5/27	200	0	0	0	200	3	Large swells
6/1	30	0	0	0	30	4	Evaded

a. Surface Dimensions of the Backdown Channel

During Set 15, the corkline surrounding the channel measured 82 fathoms from the stern tiedown spot to the backdown apex, and measured 60 fathoms from the end of the third bow bunch to the apex.

b. Underwater Observations of the Stern Wall of the Backdown Channel

The shallowing and in-folding of the stern wall of the backdown channel is termed "stern sway" and is a hazard for porpoise, because their ascent to the surface is blocked if they remain in the bottom of the backdown channel while the stern sway is formed.

Two attempts were made to observe the formation of stern sway with SCUBA gear. However, the divers were unable to satisfactorily establish communication with the tenders on the surface, so the dives were aborted and observations of the stern wall of the backdown channel were not made. Later in the trip, new NOAA diving directives, requiring an oxygen resuscitator at the dive site, precluded any further attempts at diving.

All observations of stern sway were made by personnel in rafts. In Sets 8 and 12 the development and effects of stern sway were closely observed. Stern sway was present during every studied backdown this trip. It was most pronounced midway between the boat and the backdown channel apex, decreasing in width and depth toward the apex. It completely disappeared about 8-10 fathoms from the apex, such that only very large schools of porpoise would be in jeopardy of becoming enfolded by the sway.

c. Measurements of the Depth of the Backdown Channel

Measurements were not made because SCUBA diving was halted.

d. Adjustments of the Hang-in of the Net

No adjustments were made.

e. Documentation of Backdown Control

The rudder angle, engine use, and skiff position with time were documented during backdown in Sets 2, 5, 6, 9, 13, 16, and 18. No specific patterns emerge from examination of these notes other than that the employment of these factors varies from set to set and they are used to adjust the backdown arc (or radius) of the vessel, to maintain the optimum backdown channel width.

2. Studies of Delay-causing Circumstances

There were no rollups, no fouled bunchlines, and the net was not caught on the stern in any set during this cruise. During Set 7, a series of underwater photographs were taken to document the juxtaposition of the net and vessel stern. The photographs were not useful because of underexposure.

3. Prebackdown Release

Not tested.

4. Herding Stimuli

a. Bubble Screens

Not tested.

b. Strobe lights

Not tested.

c. Underwater Flares

The responses of porpoise and tuna to white-light underwater (magnesium) flares were observed from a raft during four sets (2, 6, 13, and 18). The flares were individually suspended from the raft on 10-foot pieces of twine. Each flare produced light for about seven minutes. Neither spotters nor spinners showed any response to the flares other than their normal mild avoidance of rafts. The tuna swam by the flares without any deviation in behavior. They did not appear to be attracted or repelled by the flares either during daylight or at night.

5. Behavioral Observations

The following behavioral characteristics of captured animals were observed from a raft within the seine by swimmers free diving among porpoise schools, or from the vessel deck.

When the seine was set around a school of porpoise and no attempted escape had been observed, the spotted porpoise usually began to raft. The rafting porpoise congregated as a group in the center of the seine and formed a tight group, often touching each other. Some animals floated vertically, with their heads out of the water, while others layed parallel to the surface of the water.

As some spotted porpoise rafted, others swam around the periphery of the rafting animals and periodically dove to depths of up to 50 feet. Animals dove in groups or as individuals and remained at these depths for a few seconds to minutes prior to surfacing. The groups were generally composed of from two to 13 animals. Neonates were observed either swimming alone throughout the school or very close to adults (presumably the mothers).

The activity level of spinners was higher than that of spotters. Eastern and whitebelly spinners constantly swam and dove through and around the periphery of the rafting spotted porpoise. They dove as deeply as the spotted porpoise. Whitebelly spinners were observed leaping and spinning while in the seine. It is difficult to discern age grouping of eastern and whitebelly spinners because of their color varies only subtly with age. Spinners and spotted porpoise were not observed to group, swim, raft or dive together.

Eastern spinners were not observed to raft during this cruise.

Whitebelly spinners rafted on one occasion (Set 20) when about 100 whitebelly spinners and one spotted porpoise were captured. The animals were separated into subgroups of six to 11 individuals. There were three distinct groups of six animals each; all of the porpoise in these three groups had pronounced ventral keels and were presumed to be adult males. None of the other groups contained animals with similar keels. These porpoise were submerged about 90 percent of the time, and all the subgroups, except for the animals with keels, were seen to join into groups of 40 to 50 animals. It was possible to discern the subgroups as they mingled with each other, and each subgroup apparently remained intact when the larger group disbanded. The entire school remained calm throughout the set; they rafted, swam and dove. The solitary spotted porpoise swam through the spinners alone. During backdown, the school continued to raft; never increasing its activity level until all porpoise were backed out. Once clear of the net, the porpoise ran as a tight group.

Spotted porpoise exhibited "passive" behavior during some of the backdowns, when the porpoise were crowded into the close confines of the apex. Some spotted and spinner porpoise reacted to this situation by dropping down to the bottom of the backdown channel near the apex, where they lay virtually motionless. Some appeared to be looking at the surface commotion, while others appeared moribund.

During Set 15, a raftman releasing porpoise from an area of wrinkled corks observed a whitebelly spinner displaying passive behavior. Although it was not resting against any webbing, it exhibited the same sluggish, clumsy motions and apparent immobility about eight feet below the surface. The animal sank slowly when motionless and rose slowly when struggling.

Spotted porpoise never appeared to be afraid of human physical contact. When approached or touched, they did not pull away or change their mode of behavior, whether it was rafting, swimming or diving. Whitebelly and eastern spinners avoided any form of human physical contact. When approached or touched they would pull away or change their direction of movement.

An attempt was made to quantify the following behavioral observations.

a. Age Structure of Rafting Porpoise

The age structure of rafting porpoise was not noted.

b. Proportion of Porpoise School Rafting

The proportion of porpoise rafting in a school was estimated on one occasion. On Set 22, an observer in a raft made counts of porpoise underwater and estimated the percent of the school that was rafting. By partitioning into approximate tens, counts of 120, 140, 150, and 170 were obtained, with an estimated 50-60 percent of the animals rafting. The water was very clear, and all the captured porpoise could be seen from certain vantage points. The percentage rafting seemed high for this school and may have resulted in the disparity between the crew estimate of porpoise captured (450) made from the vessel and the estimate made by the observer in the water (145).

c. Age Structure and Numbers of Passive Animals During Backdown

The age structure and number of animals that were "passive" during backdown was noted on one occasion. During Set 13, three spotters, two sub-adults and one adult were observed displaying "passive" behavior just prior to backdown, by lying on the bottom of the net about 60 feet below the surface. They surfaced in unison after several minutes and were backed out of the net.

C. Results of Ancillary Research

1. Diet Studies

Eighty yellowfin tuna were flagged on Sets 17 and 19; five spotter stomachs were collected in Set 17; and 12 porpoise stomachs (10 spotter and two whitebelly spinner) were collected in Set 19. Sixty-one tuna stomachs were recovered during unloading.

2. Tissue Samples

a. Eyes

Eyes for aging studies were collected from 18 offshore spotters and two whitebelly spinners.

b. Tissue Samples

No tissue samples were collected for the structural lipid study, because all of the liquid nitrogen leaked away.

3. Standard Cruise Data

A marine mammal watch was stood daily by the scientific party and ship's crew; 327.5 hours of sighting effort resulted in 73 porpoise school sightings and 25 sightings of other marine mammals. The standard NMFS set log was kept for each set, and record of the vessel's activities was kept for each of the 50 days at sea.

4. Environmental Data

Expendable bathythermograph (XBT) traces were made 49 times in 39 days while the vessel was on the fishing grounds. Data on local weather conditions were recorded by the vessel's navigator on a daily basis and transmitted to WWD (radio weather station) when possible.

V. SUMMARY OF PORPOISE MORTALITY

Fifty-two porpoise were killed in six sets; three PSIS sets, two aborted PSIS sets and one gear set. The animals by species/stock were: 45 offshore spotted porpoise (Stenella attenuata), three eastern spinner porpoise (S. longirostris), two whitebelly spinners (S. longirostris), and two porpoise (Stenella spp.) not identified.

One porpoise was killed by a shark and 16 died by entanglement during the PSIS sets. Eleven porpoise died in the seine or the corral; the deaths may be attributed to crowding or the confusion caused by multiple backdowns. The other five PSIS-related deaths occurred when animals that had escaped during backdown or had been processed and released, returned to the outside of the seine or corral and became entangled. Presumably either these animals had been separated from an individual or social unit with which the bond was very strong, or the experience of going through the PSIS was so disorienting for these individuals that they failed to recognize the net barrier that prevented them from rejoining the school.

Porpoise were killed in two aborted PSIS sets. Three spotters died prior to backdown during Set 16, one was snagged in 1 1/4-inch mesh, and two died for unknown reasons. During Set 17, an apparent strong current collapsed the backdown channel while the speedboats, which were to hold the net open, were being launched; six spotters died because of entanglement in 1 1/4-inch mesh or entrapment in small canopies.

Porpoise died in one gear set. An estimated 1200 porpoise and 70 tons of tuna were captured during Set 19; thus, the net was quite crowded prior to backdown. When backdown started, the corkline on the bow side of the channel sank, allowing porpoise to spill out. The corkline did not rise when the vessel slowed its reverse speed, and backdown was terminated by kicking the vessel ahead to prevent the fish from escaping over the sunken corkline. As strain went off the net,

it became narrow and deep, forming canopies, so that virtually all of the 24 spotters and two whitebelly spinners died out of reach of rescuers.

VI. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

A. Primary Research Objectives

1. Workability of the PSIS

a. External Factors

Several external, uncontrollable factors affected the workability of the PSIS: weather, daylight, school size and species composition, porpoise behavior, and tuna.

-Weather Limitations

Weather conditions must be considered above all others, because as the weather gets worse, the hazards to personnel, porpoise, and equipment increase. The daily weather conditions for using the PSIS were subjectively classified as good on 11 out of the 43 days the vessel was on the tropical fishing grounds, marginal* on 13 days, and bad on 19 days. Generally, the weather conditions in the Eastern Tropical Pacific during the cruise period consisted of steady 12-20 knot northerly winds above the Inter-tropical Convergence Zone (ITCZ) with strong, well-developed squall lines within the ITCZ. This wind pattern, combined with the original intention to sample only whole schools of porpoise less than 500 animals, that were mostly spotters, meant that the vessel had to move continually and pass up several areas of fair weather where only large schools could be located.

During the second half of the cruise, when PSIS sets were permitted on partial schools, the only fair weather to be found was in the ITCZ between squall lines and was continually moving westward. The weather in these areas was subject to rapid deterioration and made setting the PSIS hazardous.

The first PSIS set was made in fair to marginal weather, the second was made in very good weather, and the third and fourth were made in marginal weather that deteriorated to rough and choppy weather by the end of the sets. Comparatively, weather conditions for gear sets were fair to barely workable; only four or five days were lost because of rough weather.

It is recommended that the following weather limits be set for using the PSIS.

- i. A single consistent swell should not exceed five feet,

*Marginal weather was usually considered as a chop of greater than one foot, swells greater than five feet and wind in excess of 10 knots.

- ii. The wind should not exceed 12 to 14 knots.
- iii. There should not be scattered whitecaps.

These limitations are stated singly but, of course, occur in combination and must be evaluated as such; for example, a confused swell combined with marginal wind is probably too sloppy for PSIS use. Squalls in the vicinity should be carefully checked, as they can cause rapid deterioration of local weather conditions.

-Daylight Limitations

The hours of daylight remaining after sighting a target school was the second external factor limiting PSIS use. During the cruise, almost six hours were needed to process each school, regardless of size. Thus, six hours from sighting to completion of a PSIS set should be considered a minimum, because on this cruise the animals were only measured, aged and sexed before release. Tagging or blood sampling will add to the processing time.

All the porpoise were to be processed and released before dusk, since no one was to be in the water after dark. Retrieval of the PSIS at dusk and into the night was accomplished on Set 11 without major difficulty and, although it is not recommended, a PSIS set can be extended into the night time if absolutely necessary. The weather should be flat calm, PSIS lighting system fully functional, and all porpoise should be spotters.

-School Size and Species Limitations

The third external factor affecting PSIS was school size and species composition. Although a maximum of 199 spotters was processed in a single PSIS set, the crew and scientific party felt that it might be possible to process as many as 500 spotters if the weather and time were satisfactory.

The calm behavior of spotted porpoise in the PSIS indicates the relative ease with which they can be handled in future work with the system. Eastern spinners in a school require a very high rescue and in-water handling effort; the experience in Set 11 showed this. When spinners were present, it was more difficult to transfer the porpoise into the corral, it was more difficult to use the crowder net, and tenders swimming in the corral were in constant jeopardy of being rammed by spinners swimming "blindly." Because of these problems, it is recommended that no school containing more than 50 spinners be processed through the PSIS unless specific objectives require it.

-Tuna Catch Limitations

The fourth external factor to consider was the amount of tuna captured in a PSIS set. Four tons were the most tuna taken in a PSIS set and on one occasion (Set 4), fish were transferred into the corral with the porpoise. Two large (80 lbs.) and one small yellowfin tuna swam about calmly in the corral during processing; they escaped during retrieval of the corral.

Large numbers of tuna in the corral may lead to fish dying. If this happens, sharks will probably attack the dead fish through the netting. On one set, a small skipjack died and was observed laying on the bottom of the corral. Five sharks were observed attempting to eat it through the netting. A tender dove down and threw it out before the sharks could damage the net.

b. Internal Factors

There are several internal factors affecting the workability of the PSIS; the size of the corral, the size of the work areas and chutes, the size and construction of the holding pen, personnel requirements, and some PSIS support equipment.

-Corral Size

The corral is 52 feet long, 17 feet wide and 15 feet deep. The maximum number of porpoise held at any one time was 127 spotters. However, 150 spotters probably could have been confined safely.

-Work Area Size

The work areas are 17 feet long. Some of that length is hindering as well as unnecessary because it forces the person examining the porpoise to expend extra energy pushing each porpoise down a longer chute. It is recommended that the work areas be shortened by about six feet.

-Holding Pen Size and Construction

The hexagonal holding pens gain their rigidity and shape from air pressure. The hexagonal shape can be maintained easily if the pen is not towed. Only one holding pen was deployed during this cruise and from this experience it was clear that no more than one pen could be pulled along during backdown without a potential for serious deformation and danger to the porpoise held within. To use more than one pen, each would have to be set adrift after being filled with a maximum of 75 to 100 porpoise. If five pens were used, it would mean pens and porpoise spread out over one to two miles of ocean. This situation would not be entirely unacceptable except that each pen should be tended by a swimmer and speedboat.

The Queen Mary carried six scientists and 14 crewmen. The crew was primarily busy setting and retrieving the seine, or holding the backdown channel open, so there were not enough people aboard to operate the PSIS and tend five holding pens.

To use more than a single holding pen, other pens would have to be set adrift unattended. This is not a responsible approach in terms of potential porpoise mortality. It is recommended that not more than one holding pen be deployed during PSIS operations unless the tuna vessel is accompanied by another long-range vessel carrying eight to 10 people and three or four small support boats.

-Personnel Requirements

The six members of the scientific party were able to launch and assemble the PSIS and attach it to the net with the assistance of one crewman. One scientist operated the crane, two handled the rigging and control lines on deck, two in rafts assembled the PSIS in the water, one operated the Boston whaler, and one crewman operated a speedboat. Three or four speedboats were needed to keep the backdown channel open before the PSIS was attached, or, if multiple backdowns were to occur, while the porpoise were being processed.

Assistance from two crew members was invaluable while processing the porpoise; it allowed full operation of both porpoise chutes. Thus, the time the porpoise spent in the corral was reduced. Constant tending and hand rescue in the corral was the only way to insure low mortality rates during processing. In the fourth PSIS set, the porpoise could not have been adequately tended in the holding pen without assistance from the crewmen. Retrieval of the PSIS occurred after the set was over, so seven or eight crewmen assisted with it. The scientific party probably could have managed it without their assistance, but more time would have been required and the gear would have been exposed to greater risk.

As the cruise proceeded, it was very clear that if any member of the scientific party was unable to work, it would have been difficult to use the PSIS, particularly because the low number of PSIS sets did not allow the scientists to familiarize themselves with more than one of the specific duties involved in the PSIS use, e.g., operating the crane, support boat operation or water level assembly. Working in the water or at water level for four to five hours, combined with the heavy physical labor involved in operating the PSIS, caused dehydration, sunburn, and exhaustion. Days following PSIS sets were always accompanied by soreness and some fatigue and the discovery of minor injuries. Although there were no consecutive days with PSIS sets, two in a row could have been done, but more than that would probably increase the risk of accident or injury.

-PSIS Support Equipment

Generally, all of the hardware and equipment carried functioned properly and will be described in a manuscript now in preparation at the SWFC. However, two pieces of support equipment will be discussed here.

The crane (HAIB 650 AW) used to launch and retrieve the PSIS received extreme horizontal strain at near full extension on a number of occasions during retrieval of the PSIS work areas and waiting pen. In situations where the cage to be lifted was not directly below the boom end, the boom members would shift such that a total horizontal displacement of 8-10 inches occurred at the boom tip. Even with a direct lift, the waiting pen with corral attached caused a 4- to 6-inch vertical displacement of the boom tip. This flexing of the boom under load was considered unsafe by the Captain, members of the crew, and scientific party. A close visual inspection of the boom at the end of the cruise revealed no cracks or deformation. It is recommended that if the PSIS is used again from another vessel, that a larger capacity crane be used.

Next to the crane, the most important piece of equipment, aside from the PSIS itself, was the support boat, in this case a 20-year old 17-foot fiberglass Boston whaler. It had a tri-hull, a flat interior deck, and was powered by an 85-hp outboard motor. The boat-carrying arrangement on the Queen Mary required that the PSIS support boat be launched for the duration of every set or chase that was made. The launching and raising of this fiberglass boat in rough weather caused multiple fractures and punctures in the hull that required constant attention and patching. Repeated slamming in the swells caused all of the interior fittings, including railings, seat, storage box and steering console, to break loose repeatedly, endangering not only the success of the mission but also the driver. Secure storage space was not adequate and eventually non-existent for the necessary PSIS support equipment. Being required to work in close proximity with partially submerged aluminum cages and flotation with exposed metal eyes also took its toll in terms of hull punctures that were continually being repaired. The outboard motor operated flawlessly throughout the cruise, although more power for towing the PSIS would have been desirable. It is recommended that an aluminum boat be especially designed and constructed to act as a PSIS support boat and that a fiberglass boat not be used again.

2. Whole-school Examination

Examinations of the age and sex structure of whole schools of porpoise was one of the reasons the PSIS was designed and built. Whole schools of porpoise were captured in six sets during the cruise (11, 13, 15, 17, 20, and 22), but because of weather, hour of sighting, school size or species, and operational problems, only one whole school (Set 11) was examined through the PSIS.

After the initial "shakedown" PSIS sets (3 and 4), the objective was to use the PSIS on whole schools only, until half of the cruise time was over. During that period, at least two schools were bypassed which could have been examined. However, they were too large and would have had to have been split so that manageable portions of the schools could have been captured. Avoidance of capture also played a major role in holding down the number of whole schools examined. On 15 of 22 sets, part or all of the school pursued escaped capture. Evasive techniques used by the porpoise to escape capture are interesting to study from a strictly behavioral point of view. However, from the point of view of using the PSIS to sample the porpoise stocks for age and sex composition, porpoise evasive techniques offer serious problems of bias in the estimates. If the animals that escape are a random portion of the population, then the age and sex ratio gained from examining a partial school could be applied to the population as a whole. However, for example, if only vigorous young males escape, the apparent proportion of females in the population would appear higher, or vice versa. The only recourse is to sample the porpoise extensively with the PSIS, and increase the number of whole schools examined.

Interpretation and analysis of the school structure data presented in Table 5 for three partial schools and one whole school are premature for this report; however, the ratios of spotted porpoise examined, 38 percent males and 62 percent females, are not surprisingly different from previous estimates.^{1/}

3. School Size Estimates

Using the PSIS, a fairly accurate count of captured animals was made on four sets. Those data were to be compared with estimates made by crewmen and experienced scientists; however, both the crew and the scientific party could not record their estimates of the number of captured porpoise until after the school had been processed. This was less than ideal because of the opportunity for conscious or unconscious bias in the post-set recording of estimates. For future cruises in which school size estimate calibration is an objective, this opportunity for bias should be minimized. The set process should come to a halt when the purse rings come up and estimates should be collected by a non-estimating scientist. If the process cannot be stopped, a seventh scientist would be needed to gather the estimates on a timely basis.

B. Secondary Research Objectives - Mortality Reduction and Behavioral Research

^{1/}Perrin, W.F., J.M. Coe, and J.R. Zweifel. 1977. Growth and reproduction of the spotted porpoise. *Stenella attenuata*, in the offshore eastern tropical Pacific. *Fish Bull.*, U.S. 74(2): 229-269.

Many of the mortality reduction research objectives were not accomplished or attempted, because all of the at-sea planning was directed towards maximizing the effectiveness of the PSIS.

SCUBA diving, needed for studies of the dynamics of the backdown channel, was first curtailed by the failure of the diver-to-surface communication system and then eliminated in mid-cruise by a change in the NOAA diving regulations. Future work of this nature will require that it be the major objective of the cruise. The establishment of a simple and foolproof, non-electronic, diver-surface-diver signal system is a necessity.

Insights as to the causes of stern sway were obtained from surface observations of the backdown channel. Stern sway is a natural result of backing down. The main line of force of backdown is along the floor of the channel to the apex. As the vessel goes astern the line of force from the ring stripper along the floor of the net to the apex attempts to become a straight line, while webbing from the floor to the corkline on both the bow and stern sides becomes slack as the floor rises. As the vessel is backed down in a slight arc to port, the resistance of this slack webbing, regardless of mesh size, will cause it to be carried to starboard of the line of force forming the stern sway. Since the corkline is secured at both bow and stern and must follow the vessel, the corkline acts as the upper line of force to which the slack side walls of the channel are pinioned. Thus, stern sway is a natural effect of backdown. As such, no structural remedy for stern sway has been devised although procedural steps were recognized which may reduce the formation.

It had been hypothesized that the shape of the webbing in the stern wall of the net prior to backdown has some effect on the degree and severity of stern sway. From observations in Sets 8 and 12 and others throughout the cruise, it appears that this is not the case. Rather, the orientation of the entire net to the vessel at the start of backdown affects the rapidity with which stern sway develops.

Any effort that will help to form the backdown channel off the port bow prior to engaging the engines will diminish the stern sway problem. Use of the seine skiff, bowthruster and occasional brief use of the main engine(s) can help to "pre-form" the backdown channel. Once the vessel goes into reverse, care should be taken not to allow the arc of backdown to become too tight, which causes the backdown channel to curve and increase the cross flow of water. Minimizing cross flow will minimize stern sway.

The opportunity to observe problems such as roll-ups, tangled bunchlines and entanglement of the nets with the stern did not occur on this trip, but these objectives should be maintained through the remaining trips of the Dedicated Vessel.

Underwater photography is limited by available light, visibility and the skill of the photographer. Some useful photographs were obtained

regarding the relationship between the PSIS and porpoise. All future cruises using the PSIS or SCUBA diving should include at least one underwater camera and a strobe light.

VII. PERSONNEL

James M. Coe, Cruise Leader, NMFS
Jacqueline G. Jennings, NMFS
Warren E. Stuntz, NMFS
James F. Lambert, NMFS
William A. Walker, NMFS Contractor
Charles B. Peters, LMR

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IX. SUBMITTED BY:

James M. Coe
James M. Coe, Cruise Leader

Jacqueline G. Jennings
Jacqueline G. Jennings

Charles B. Peters
Charles B. Peters

John DeBeer
John DeBeer, Program Manager

X. APPROVED BY:

William F. Perrin
William F. Perrin, Member, Program Board

Robert G. Hofman
Robert G. Hofman, Member, Program Board

Frank Alverson
Frank Alverson, Member, Program Board

Appendix A

A Summary of Individual PSIS Sets

Set #3: The purpose of the first PSIS set was to capture and process less than 50 spotters, to answer questions concerning the workability of the system regarding mortality levels, time requirements, behavior of porpoise while impounded, and ability of the personnel to handle and process the animals. The set was made in a 10-11 knot northerly breeze and a three-foot swell with a one-foot chop and scattered whitecaps.

An estimated 138 spotters out of an estimated school of 575 spotters were captured, too many for the initial test of the system, so only a portion of the school was backed into the corral. At the seine/corral interface, many of the porpoise in the corral were trying to return to the seine or were fighting the corral gate and becoming entangled. Considerable hand-rescue effort was required here, and about 20 porpoise escaped between the corral and seine or over the seine corkline. At the end of the first backdown, the apex area of the seine started to collapse on the remaining porpoise, so it was decided to cut the PSIS loose and back down a second time to free these animals. With the PSIS drifting free, the majority of the porpoise in the corral began to settle down to rafting or slow swimming. There were 16 animals that had to be hand released because they continually fought the net and would very likely have become entangled and drowned.

The crowder net was placed behind the remaining porpoise, and two skin-divers tended the animals in that area. Processing began immediately and continued, with short interruptions to pull in the crowder net, until all 66 porpoise were examined and released. About 30 minutes were used to process the animals. Most of these animals were reasonably docile and could be caught and delivered to the work areas with little difficulty. Once in the chute, many of the porpoise arched dorsally or laterally, making accurate length measurements difficult but not impossible. A few attempted swimming in the chutes but usually settled down in a few seconds. As they slid over the end of the chute to open water, virtually all seemed to relax and swim directly down and away at about a 45° angle. In this set it was rare to observe any animals break the surface after release. One neonate was eaten by a shark as it raced around outside the PSIS, the only kill during this set. From the wild behavior of the porpoise during and after backdown at the seine/corral interface, it was thought that without the escape and release that occurred, the mortality could have run as high as 20-30 percent of the animals captured. This school was sighted at 1017, and the PSIS was back on board at 1600, for a total time of five hours and 43 minutes.

Set #4: The second PSIS set was made on a portion of a mixed school, to ascertain what mortality level might be sustained if every effort was made to hold and process every porpoise captured, and if multiple backdowns were performed. The school was sighted at 0800 and was estimated at 692 porpoise, 95 percent offshore spotters and five percent eastern spinners.

The net was let go at 0850, and an estimated 269 spotters were captured. The weather was a Beaufort 3 with 10-knot northeast winds, a light chop and a 4-foot swell. The weather improved as the set continued. Launch, assembly and attachment of the PSIS went well, except that the corral was in the way of speedboat launching. This delayed the attachment of speedboats to the net for holding while the corral spreader bars were removed to permit launching.

Two backdowns were required to process all of the porpoise. The crowder net was used to close off the corral gate after each backdown when raftmen had cleared the area of porpoise.

In the first backdown, 127 animals entered the corral and 41 were counted escaping over the corkline outside of the corral. The momentum of backdown carried the rafting spotters all the way through the corral, so that they piled up in the shallow water of the waiting pen. When backdown stopped they moved out of the shallows and back out to the far end of the corral by the crowder net where they resumed milling and rafting. This behavior was seen for spotters in each of the PSIS sets. Fifty-five minutes were used to process these 127 porpoise.

In the second backdown, the seine was emptied of live porpoise; 67 entered the corral and another 20 were counted escaping over the corkline. It took 24 minutes to process and release these animals. Five porpoise were killed in the seine, and three died in the corral (see mortality discussion below). The entire process, from sighting the school to getting underway again, took 5 hours and 45 minutes. One crew member assisted during backdown and processing of this school; this assistance enabled full operation of both chutes.

The vessel navigator was asked to make some notes on his impressions of the behavior of the porpoise as they were released after processing, since the full scientific party was working at water level during the PSIS sets. From the bridge he observed that:

- The porpoise reaction to being freed was similar to release during backdown, except that they ran more slowly and the leaping was abbreviated.
- There was some disorientation with respect to direction of flight noted.
- The school scattered in several directions with some of the porpoise returning to the boat and net area.
- A neonate was observed milling around outside the net apparently trying to get back inside. It was speculated that it was separated from its mother.

The accidental loss of porpoise over the corkline during this set was recognized as a serious problem with respect to future whole-school examinations and tagging studies. The remedy was to use spare work area inflatables to buoy the corkline on either side of the corral opening.

Set #11: This was the only time it was possible to capture and examine almost an entire school. The school was estimated to contain 250 porpoise, 66 percent offshore spotters and 34 percent eastern spinners. The school was sighted at 1210 and the net was let go at 1259. The initial target of the whole-school work had been primarily spotters but permission to test the PSIS on spinners as well had been received. Extra flotation had been added to the corkline, and only seven animals escaped in the course of three backdowns. Eight porpoise were killed in this set; two in the seine, one in the corral and five entangled on the outside of the corral or the seine.

The behavior of the eastern spinners both in the corral and in the seine required a considerable increase in the efforts to back them into the corral, crowd them, catch them and process them through the chutes alive. Throughout the set the spinners never settled down by milling and rafting as the spotters had done in previous sets. They were continually dashing about, ramming the corral bottom, the sides and pushing the crowder net out of shape. Two crew members assisted in handling the porpoise on this set. Thus, at least three and up to five swimmers were always actively involved in rescuing the animals as they became entangled. The high activity level of the spinners also seemed to keep the spotters more active in the corral. During processing after each backdown, a few, usually adult male spinners, would succeed in getting around or under the crowder net and had to be wrestled to the waiting pen by three or four swimmers. Most of the spinners had to be caught and physically carried to the chutes, as they struggled vigorously to escape. In all, 81 spotters and 43 spinners were processed and released alive out of the estimated (after processing) 136 porpoise captured. As a result of the difficulty in handling the spinners during this set (several swimmers suffered multiple bruises from being rammed), it was decided to avoid PSIS sets on schools with more than about 50 spinners captured.

The PSIS was back on board at 1810 for a total elapsed time from sighting the school of six hours. At the start of the set, the weather was a Beaufort 3-4 with scattered whitecaps and a 4-foot swell, which was considered marginal for using the system. As the set progressed, the weather increased to Beaufort 5 with steady whitecaps, a chop and a 5-foot swell. This made handling of the PSIS, data recording in the support boat, and general movement within the PSIS difficult and dangerous.

The general consensus of scientists and crew was that those weather conditions put as much strain on the PSIS and its personnel as they could handle safely. If something had broken or gone awry, it would have been difficult and dangerous, both to the porpoise and the people, to correct the problem or abort the set.

Set #21: As the end of the cruise period approached, the highest priority was to deploy and hold up to 100 porpoise in a hexagonal post-processing holding pen to evaluate their behavior and to test the feasibility of using up to five such pens simultaneously. A school estimated to contain 103 porpoise, 55 percent spotters and 34 percent eastern spinners, was sighted at 0850 and set on at 0931. Fifty-six porpoise were captured, all offshore spotters. Three escaped in the single backdown required, and 53 were examined and released into the

holding pen. These animals behaved similarly to the spotters captured in Set 4 and were processed in about 31 minutes with no mortality.

The holding pen was launched and moved into position at the ends of the work areas, which added 20-30 minutes to the pre-backdown time period. Two or three crewmen assisted in most phases of this set. They were absolutely necessary for tending porpoise in the holding pen while the scientific party was processing the remaining porpoise from the corral. The first three or four porpoise to enter the holding pen appeared disoriented and bumped into the webbing a few times before settling down to rafting and milling in the center. No rescue was required and subsequent animals entering the pen joined the now-oriented group, thus, avoiding contact with the walls of the pen. The pen held its shape during backdown and processing, but as soon as the corral was separated from the seine the pen was folded by the wind and swell against the work areas. Four swimmers kept the porpoise moving out of collapsing areas while the support boat and another speedboat towed the pen clear of the work areas and pulled it back into shape. This was a tense time because the surface area of the pen was reduced by about 75 percent at one point. The animals remained calm and were easily herded, pushed and shoved out of danger areas by the swimmers. Once the inflatables were fully reinflated and the holding pen was back in its normal hexagonal shape, it drifted without deforming until the porpoise were released 7 hours later.

The porpoise occupied 1/4 to 1/3 of the volume of the pen in a broad cone shape, circling in both directions beneath rafting and slowly moving animals at the surface. Several small "two-tones" were very active throughout the holding period and regularly left the group and returned. The body of porpoise would shift off the center of the pen to keep its distance from the tender (at least one was swimming in the pen at all times) while he was at the surface but showed little or no avoidance to the tender if he was underwater and swimming among them. Aggressive behavior was rarely noted and then only for short instances between individuals in the form of tooth raking, biting, and quick fluke snaps. One small two-tone was seen nursing on several occasions. Nightfall had no observable effect on the behavior of the penned porpoise, but it made it difficult for the tender to see the walls of the net, so that sharks approaching the opposite side of the pen appeared to be inside it.

The scientific party and members of the crew took turns tending in the pen. One silky shark (Carcharinus falciformis) was shot with a .38-calibre bang stick because it was pushing against and biting the webbing of the pen from the outside and causing some increased activity in the porpoise. A number of other silky and oceanic whitetip sharks (Carcharinus longimanus) inspected the pen but departed without incident. During the entire operation, a neonate spotter circled and dove outside the pen as if its mother were inside. It had some close calls with the sharks but departed with the porpoise when they were released. About an hour into dark, the Captain ordered the pen tender out of the

water, so at 1938 the gate was partially opened. It took the porpoise several minutes to find the opening and another 15 seconds for them to depart.

The weather at the start of the set was fair; a 10-knot breeze, 3-5-foot swell and no whitecaps. By late afternoon it had increased to a 15-knot plus breeze, was very choppy, with frequent whitecaps in a 6-foot swell. The weather increase had no effect on the holding pen shape or the porpoise behavior but did make waiting in the support boat for one's turn as tender more uncomfortable.

The school was sighted at 0850, and all PSIS gear was aboard by 1410 except for the support boat and the holding pen. The holding pen was aboard at 2005. The porpoise were held 7 hours and 45 minutes, to simulate the time they might have had to spend in the pen had 500 porpoise been captured, processed and tagged, (requiring the use of five holding pens).

A Summary of Individual Aborted PSIS Sets

Set #10: At 0745 in marginal PSIS weather the net was let go on a whole school estimated at 500 porpoise, 40 percent offshore spotters and 60 percent eastern spinners. While pursuing, an estimated 100 spinners dove under the net and escaped. The PSIS was prepared for launching, but when the rings came up, the high percentage of spinners was easily seen and the decision was made not to attempt to process that many spinners on the first attempt at examining spinners using the PSIS. Additionally, a large bow bend formed that would have delayed the launching of the PSIS by 20-30 minutes. The set was made with the wind on the starboard bow, thus increasing the chance of net collapse in the event of a serious gear malfunction. The weather was marginal, a Beaufort 3-4 with frequent whitecaps and a lively 4-5-foot swell. One ton of tuna was loaded, no porpoise were killed, and the set was finished at 0930.

Set #14: A school estimated to contain 2100 porpoise, 50 percent offshore spotters and 50 percent whitebelly spinners, was chased in an attempt to capture 300-400 spotters. The set was made at 1143, capturing about 300 porpoise, 95 percent whitebelly spinners. The ratio of spinners was verified from the mast at "rings up," and in light of the difficulty of processing 43 spinners in Set #11, the PSIS was not used. No porpoise were killed, no tuna were caught, and the set was finished at 1330.

Set #16: A whole school estimated at 194, 97 percent offshore spotters and 3 percent whitebelly spinners, was captured at 1018. The PSIS was readied for use but was not used because of a fairly large swell of 8-10 feet that was confounded by one or two lesser swells from different directions. This resulted in a very active and unpredictable sea surface. Two speedboats had broken down during the chase, so there was also some doubt as to whether the net could be held open prior to and between backdowns with the PSIS attached. Five tons of tuna were loaded, and three female spotters were killed by entanglement before backdown.

The set was completed at 1240. A large squall came toward the boat during the latter stages of this set, making the sea even rougher. Gear observations were made from rafts during this set, although it is not classified as a gear set.

Set #17: At 0815 the set was made on an estimated 233 spotters, and the whole school was captured. The weather was very good except for a single long ground swell of 7-8 feet that was so gradual in its motion that it would not have been a problem for the PSIS. The corral and waiting pen were launched and alongside when the speedboats were launched to hold the net open. During launching of the speedboats, the backdown area began to collapse rapidly because of an apparent subsurface current. The porpoise began to enter canopies and also started to escape over the corkline by the time two speedboats had hooked up. The speedboats were not able to alleviate the collapse, and the porpoise continued to escape. To prevent a very high kill, the PSIS mission was aborted. The corral and waiting pen were set adrift and the porpoise were backed out of the net. Six porpoise were killed, all females, and 35 tons of yellowfin tuna were brailled. The corral and waiting pen were retrieved and on board by 1230.

